The Automation of the Painting Process

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***Abstract*—The paper depicts the concepts of automated painting of electric motors. The most suitable concept, involving two robots, is suggested for realisation, but further painting process analysis and experiments are needed.**

***Keywords*—painting; robotics; automation; planning; design; electric motor**

I. Introduction

Automation of production processes is the global trend in industry, implying not only technical and economic but also social changes. The development of automation and robotics enables their breakthrough in smaller production volumes carried by medium-sized and smaller companies. Robots and manipulators are today reasonably priced, and their implementation in production processes allows making of cheaper and more quality products.

This paper deals with the possibilities of automation of the painting process of the electric motors in the company Končar-MES d.d. Tens of thousands of electric motors are produced each year regularly. Currently, the painting process in the company is performed manually, but at the same time, the project aimed at realisation of automated transfer of electric motors during painting is just in progress. Hence, this work has purpose to integrate automatic painting cells with(in) automated transfer system (hanging conveyor) [1]. To do that, prior to design of technical solutions, it is necessary to analyse the painting process itself.

II. Painting Process

In the painting process of electric motor, there are three main types of layers: the primer, the intermediate and finish layer (Fig. 1). The purpose of the primer layer is to protect the material from corrosion and to facilitate adhesion of subsequent layers: it is set to the previously sandblasted or polished, the cleaned metal surface, to effect adhesion.

Finish Coat(s)
Intermediate Coat(s)
Primer Coat(s)
Surface Preparation
Substrate (Steel)

Fig. 1. Layers of paint on workpiece [2].

After the primer layer, intermediate layer is set with intention to enable the workpiece comprehensive protection: it provides additional protection against corrosion, slows down oxidation and prevents the absorption of moisture in humid atmospheres. Sometimes, the practice of manufacturers is not to use the intermediate layer because the specification is very similar to the primer layer. Then, instead of the intermediate layer, there is few layers of primer coating. The final layer, in addition to affect the aesthetics, provides protection from the effects of the sun and reduce the amount of condensation on the surface.

As it was stated previously, the process of painting is currently performed manually and it is not fully technically described, what is crucially needed for process automation.

In order to approve the process of painting, it is analysed, especially from the point of automation capabilities. The technology of spray guns is also considered, which could contribute with saving of material and increase of quality.

The determination of appropriate painting parameters is a necessary step in ensuring the quality, efficient transmission of the paint, the desired layer thickness (δ) and the elimination of defects (such as non-coloured areas or unwanted paint clusters).

There are several variables that affect the painting process:

- the flow of paint, Q_b, m^3/s
- distance between nozzle and the workpiece, L, m
- workpiece geometry
- technology of the process (HVLP, LVLP, electostatic, conventional)
- conveyor speed, v_c, m/s
- moving speed of the nozzle, v_m, m/s
- pressure of air entering the nozzle, p, bar
- exchangeable hole diameter at the top of the nozzle
- fan geometry.

Paint coating typically consists of multiple operations before and after the actual coating process [3]:

- Part fabrication
- Part preparation
- Part presentation
- Multi-step coating process
- Curing
- Part handling
- Vision inspection.

III. Painting Methods and Choosing a Spray Gun

Kind of painting method and type of nozzle in automated paint system are important factors that will mostly affect the final product quality. Correct choice of the method and nozzle depends on the geometry of the workpiece, the quality demands, operation speed, investment and limitations of the method of coating in which the nozzle is used.

The most common methods are:

- electrostatic
- HVLP – *High-Volume/Low Pressure*
- LVLP – *Low-Volume/Low Pressure*
- conventional.

The analysis [1] revealed the advantages, disadvantages and limitations of certain painting method, and HVLP method appears to be the best choice. That process meets the requirements for quality, speed of operation and the possibility of integration in the planned system.

IV. Technical Solutions of Automatic Painting Process

Several technical solutions – concepts of automatic painting process and system are developed [1] and will be presented in the following sections with their advantages, disadvantages and limitations. The concepts are designed using the software CATIA/DELMIA (CAD/CAE/CAM software, including process planning and off-line programming) [4].

A. Manipulator with Circular Nozzles

Manipulator can be observed in two variants, as a static (fixed) or linearly displaceable via an additional linear axis (Fig. 2). In both cases, Fig. 2 does not show the ways of manipulator fixing.

Advantages of this concept are:

- parallel use of multiple nozzles can make the process faster
- a good solution for workpieces of larger length and a constant diameter
- compactness
- simple kinematics (uniaxial motion)
- possibility of in-house manufacturing using standard components (usually cost-effective).

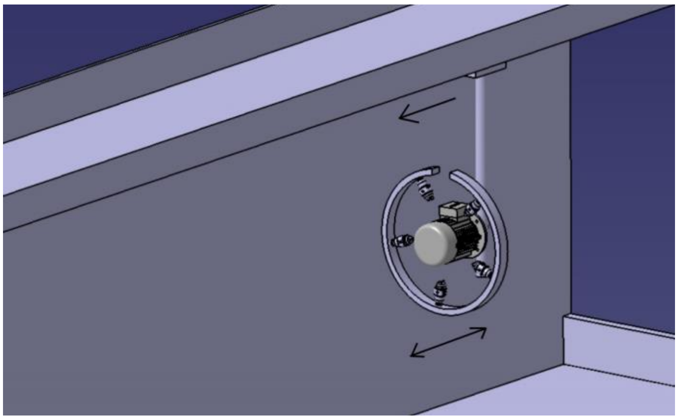


Fig. 2. Manipulator with circular nozzles.

Disadvantages, in a case of larger range of products of different sizes:

- the nozzles will not have a constant distance from the workpiece: to some extent – for smaller differences in sizes, it is possible to change the painting parameters; after that, however, the nozzles should be movable
- impossible to use one hanger (suspension carrier) of the transfer system for two workpieces (electric motors)
- need for an additional axis (for circular manipulator) or speed adjustment of the existing conveyer for electric motors
- device cannot be converted (it is dedicated)
- the need for a larger number of nozzles
- the need for a strong compressor that will simultaneously serve all nozzles
- unavailability of such equipment on the market, special order or own construction and in-house work needed
- inability of integration of system for automatic cleaning of nozzles.

Specific disadvantages – limitations of this concept regarding electric motors are:

- not applicable to electric motors due to the inability to reach the fan cover
- due to the complicated geometry of the electric motor there is a possibility of occurrence of untreated surfaces.

B. Linear manipulators

Linear manipulators are very often a solution in the painting process for mass production. They usually contain two degrees of freedom with the possibility of adding one more (integrated on linear track system; external axis or track manipulator). The concept consisting of three linear manipulators for painting of electric motors is shown by Fig. 3. One of the manipulators is placed on rails (track manipulator) and there is a possibility of collision with transfer system (hanger which carries the workpiece).

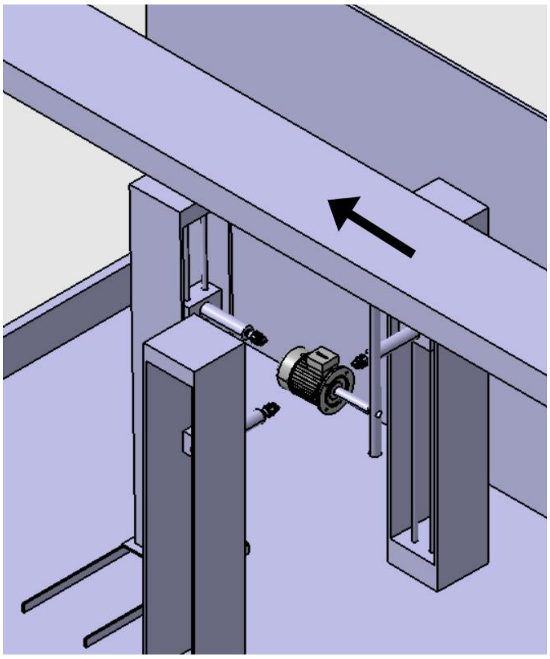


Fig. 3. Linear manipulators.

Advantages:

- speed of operation
- practical solution for flat geometry
- placing more nozzles on the manipulator can speed up the process
- possibility of painting of more workpieces on the same hanger.

Disadvantages of the concept:

- the need to combine manipulators in order to cover whole workpiece surface intended for painting
- requires buying or own construction of linear track system
- needs a stronger compressor that will simultaneously serve more nozzles
- inability of integration of system for automatic cleaning of nozzles.

Limitations of this concept regarding electric motors are:

- a possibility of occurrence of untreated surfaces
- inability to reach one side of electric motor's control box.

C. Industrial robot

Industrial robots are used in many operations, such as welding, machining, painting, handling, packaging, palletising and other.

The previously mentioned concepts (principal technical solutions) have shown that the (manipulator) systems of three degrees of freedom, even combining several manipulators, hardly, or with difficulties, reach all surfaces to be painted, especially complex surfaces, such as those of electric motors. Therefore, it is obvious that painting with robots must be considered.

Manufacturers of robots for painting applications suggest robots which have six degrees of freedom, so for example, Yaskawa offers the following robots shown in Fig. 4. Among them, the smallest one, EPX1250 seems the most suitable to do the job of electric motors painting.

However, the solution with one robot shows the inability to reach some areas of workpiece as well as collision risk, despite the size of robot (Fig. 5).

The above problem can be solved by including another robot EPX1250 (Fig. 6 and Fig. 7). So, the second robot ensures application of paint over the entire surface, and moreover, the process will be carried out in a shorter time due to the parallel work of two robots.

Fig. 4. Robots applicable for painting [5].

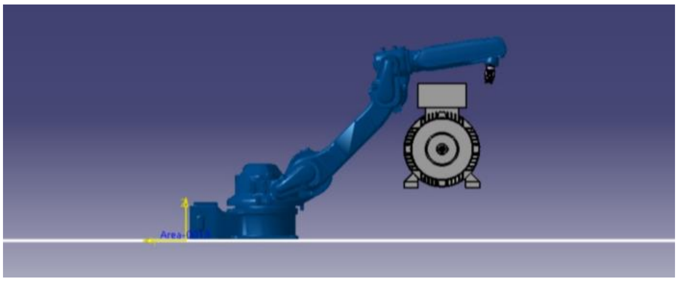


Fig. 5. The inability of the robot EPX1250 to reach all the required areas of the workpiece.

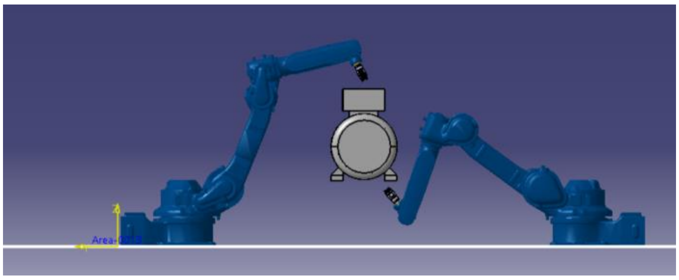


Fig. 6. Two EPX1250 robots can reach all the areas required for painting.

Parallel work of two EPX1250 robots is designed by the software CATIA/DELMIA: the simulation was run and data on productivity and cycle-times were estimated. That included the determination of painting/nozzle paths (trajectories). The painting path is divided into three segments (Fig. 8): painting of control box, housing and fan cap. Fig. 9 and Fig. 10 provide recommended trajectories: green dots there represent the starting point, while the red ones the endpoints of movements.

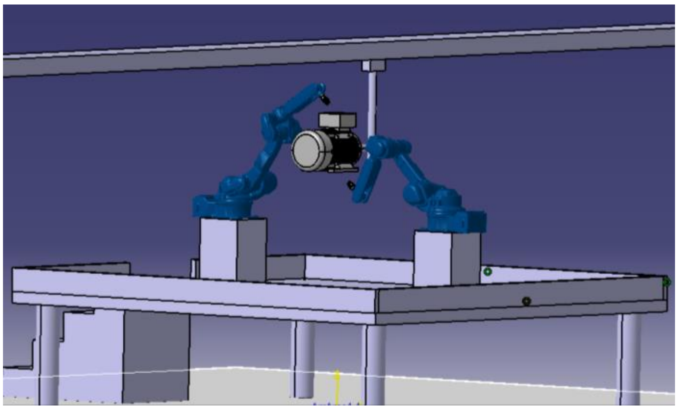


Fig. 7. Parallel work of two EPX1250 robots.

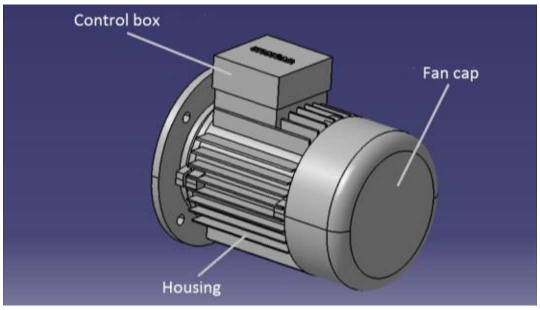


Fig. 8. Parts of the electric motor intended for painting.

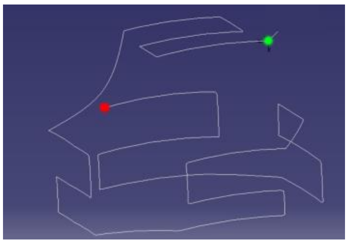


Fig. 9. The electric motor painting: trajectory for control box.

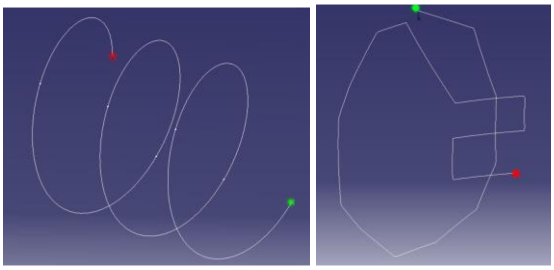
a)  b)

Fig. 10. The electric motor painting: a) trajectory for housing, b) trajectory for fan cap.

Advantages of using of two robots are:

- the possibility of the movement adequate to complex geometry of workpiece
- fine movements allow to maintain a constant and optimal distance between nozzle and the workpiece
- compatibility with automatic systems for cleaning of nozzles
- synchronous work of two robots speeds up the painting process
- software support for (painting) process digitalisation (simulation, programming).

Disadvantages of using of two robots are:

- more expensive solution compared to circular and linear manipulators
- two robots required to cover the entire surface of the electric motor
- more space required for placement of the two robots.

The basic cost of two robots is cca 60 000 EUR.

Also, defining the appropriate trajectory is the basis for planning the automatic painting process.

V. Conclusion

Among here in the paper presented principal technical solutions for automatic painting of electric motors, the solution with two robots seems the most promising one for future elaboration and detailing.

It is obvious that such solution can significantly contribute to the painting process of electric motors in terms of productivity and quality, but a lot of further efforts should be done, especially regarding precise determination of painting parameters including the most suitable (optimised) robots' painting paths. Despite present market offers on existing equipment and solutions, introduction of automation for a product in a company always require special attention and creative experiments.

Acknowledgment

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